

## Branching and Terminal Growth of Western Redcedar

### Abstract

Western redcedar (*Thuja plicata* Donn), family Cupressaceae, exhibits morphology quite distinct from its coniferous associates in the Pinaceae. Young Pinaceae trees can be reasonably aged, and past growth rates determined at a glance using major branch whorls. This is not true of western redcedar, or other members of the Cupressaceae. Growth morphology of western redcedar is described in terms of buds, leaves, and branching pattern as observed and measured in northern Idaho. A simple, nondestructive technique for aging western redcedar terminals for the previous three to six years is outlined. This technique for terminal location and aging appears adaptable to other members of the Cupressaceae.

### Introduction

While investigating natural regeneration of western redcedar (*Thuja plicata* Donn) in northern Idaho (Parker 1979), we were faced with the problem of determining height, age and growth rate during each of the past several years. Western redcedar, in the family Cupressaceae, does not follow the familiar and regular growth pattern of its coniferous associates of northern Idaho (all members of the Pinaceae) in which a major whorl of branches on the main stem locates the beginning of each year's growth.

Thus, for two years, growth increments were observed on numerous western redcedar individuals. From these observations a method is described for finding the terminal, a feature deceptive in its location. Growth patterns are also described so observers can accurately measure annual height increments for the past several years.

Nondestructive aging of regeneration can provide quick and accurate height growth information; such knowledge is fundamental when evaluating the suitability of various sites and stand conditions for the growth of western redcedar.

### Methods

Fifty-eight young cedars were dissected and comparisons made between growth rings and branching patterns. Measurements of leader growth on 35 young trees were made for one growing season on a variety of sites, including a middle-aged stand, road cuts and a clearcut. These observa-

tions coupled with the dissections resulted in methods for accurate location of terminals and determination of past years' height growth.

### Morphology

To appreciate the complexity of western redcedar growth, a review of morphology is beneficial.

#### Buds

Western redcedar has buds without preformed shoots (Laubenfels 1953). Instead there are very small terminal resting buds which lack bud scales (Mitchell 1965, Aldhous & Low 1974), although buds are covered by numerous leaf primordia at various stages of development (Owens & Pharis 1971). Mitchell (1965) noted that *Thuja* shares this type of bud with *Chamaecyparis*, *Cupressus*, *Juniperus*, *Libocedrus* (all Cupressaceae), *Metasequoia* and *Sequoia* (both Taxodiaceae). Individuals of these genera are slow to start growth in the spring but grow steadily over a long growing season.

Kozolowski and Keller (1966) divided conifers of the temperate zone into two widely differing groups based on their shoot elongation. The first group, "predetermined," encompassing most of the Pinaceae, have buds which contain preformed shoots that are formed late in the growing season. After bud break in the spring, shoots elongate. It is possible for these trees to have a second flush of growth resulting in lamma shoots, typical in *Abies*. These "extra" shoots also rise from buds containing preformed shoots. After their extension another preformed shoot is produced to

overwinter as a bud. Kozolowski and Keller's (1966) second group, "non-predetermined," are certain members of the Cupressaceae, including *Thuja*, and Taxodiaceae; these have winter buds which do not contain fully preformed shoots. Both early and late leaves may be formed during the growing season of their expansion. No strong initial whorl of branches is produced, instead a series of more-or-less equal branches are produced throughout the growth period (Figure 1).

Predetermined trees (*Pinaceae*) complete shoot growth early in the growing season and there is a high correlation between shoot growth and previous year's weather. In contrast, non-predetermined trees (*Cupressaceae*) presumably use food reserves for initial elongation but use carbohydrates produced in the current season for further elongation. Williams (1968) found the height growth of western redcedar correlated well with current year's weather. A plausible explanation for this high correlation involves the lack of preformed shoots in western redcedar, and the use of current years' photosynthate for continual shoot elongation.

In our study, slow-growing, shade-suppressed trees often grew several centimeters early in the season and stopped. More vigorous open-grown trees grew early in the season, stopped in late summer during moisture stress, but resumed growth after fall rains had commenced, illustrating the environmentally responsive growth of western redcedar.

Mitchell (1965) found the pattern of growth and type of resting bud was closely correlated in conifers. He believes trees with very small buds and no predetermined shoot must make new tissue as conditions become favorable, hence the slow start in the spring. But, on the other hand, since they have little or no bud to prepare for winter they can continue growth as long as conditions permit, resulting in a long growing season. In this way western redcedar can respond if improved conditions occur late in the year.

We often found adventitious buds at the swollen branch junctions on main stems. From these buds may come more lateral branches or a new terminal if needed. In this study the terminals of three small western redcedar sample trees were browsed during the winter; all three had developed a new terminal by the following midsummer.

## Leaves

Western redcedar usually has two wide, linear cotyledons which are flat in cross section (Figure 2-A). They are persistent but generally die after the first season. Juvenile leaves are subulate and flattened. These are mostly in whorls of four, although we found individuals with whorls of three (Figure 2-B&C). Juvenile leaves are slightly decurrent; the majority of the leaf extends at a right angle to the main axis. Vigorous seedlings may branch and produce mature foliage during the first year, but slow growing individuals may produce only juvenile leaves for several years (Figure 2, D). After these early years juvenile leaves are not normally formed. However, after an injury, vigorous small trees may exhibit juvenile leaves.

Mature leaves are scale-like and completely decurrent. They are opposite on larger stems and appear to be in whorls of four on branchlets. There are two flat facial leaves which bear minute glands, the under leaf also bearing distinctive stomata bands. Facial leaves are embraced by a pair of smaller, keeled lateral leaves. As the twig elongates, lateral and facial leaves gradually separate, become more similar morphologically and eventually are opposite on the main axis (Figure 1). On these fern-like branchlets the stomata are concentrated on the underside and are marked by glaucous, patterned stomatal bands. These leaf descriptions concur with those of Laubenfels (1953), Franklin (1961), Bowers (1965) and Owens & Pharis (1971).

## Branching

At the terminal, and on the laterals, new branches in western redcedar are formed one at a time, originating from stem leaf axes on alternating sides. Side branchlets arise from the axes of lateral leaves. The main stem is round in cross section and branching occurs on even numbers of leaf pairs. This sometimes forms branches in one plane, but usually the main stem twists giving the appearance of branches radiating around the main axis. The smaller, flattened branchlets twist also, orienting themselves in a horizontal plane in shade situations or vertically under sunny conditions. It is interesting to note that without these twists, western redcedar would be completely flat, lying entirely within one plane, since it branches only on lateral leaf pairs.

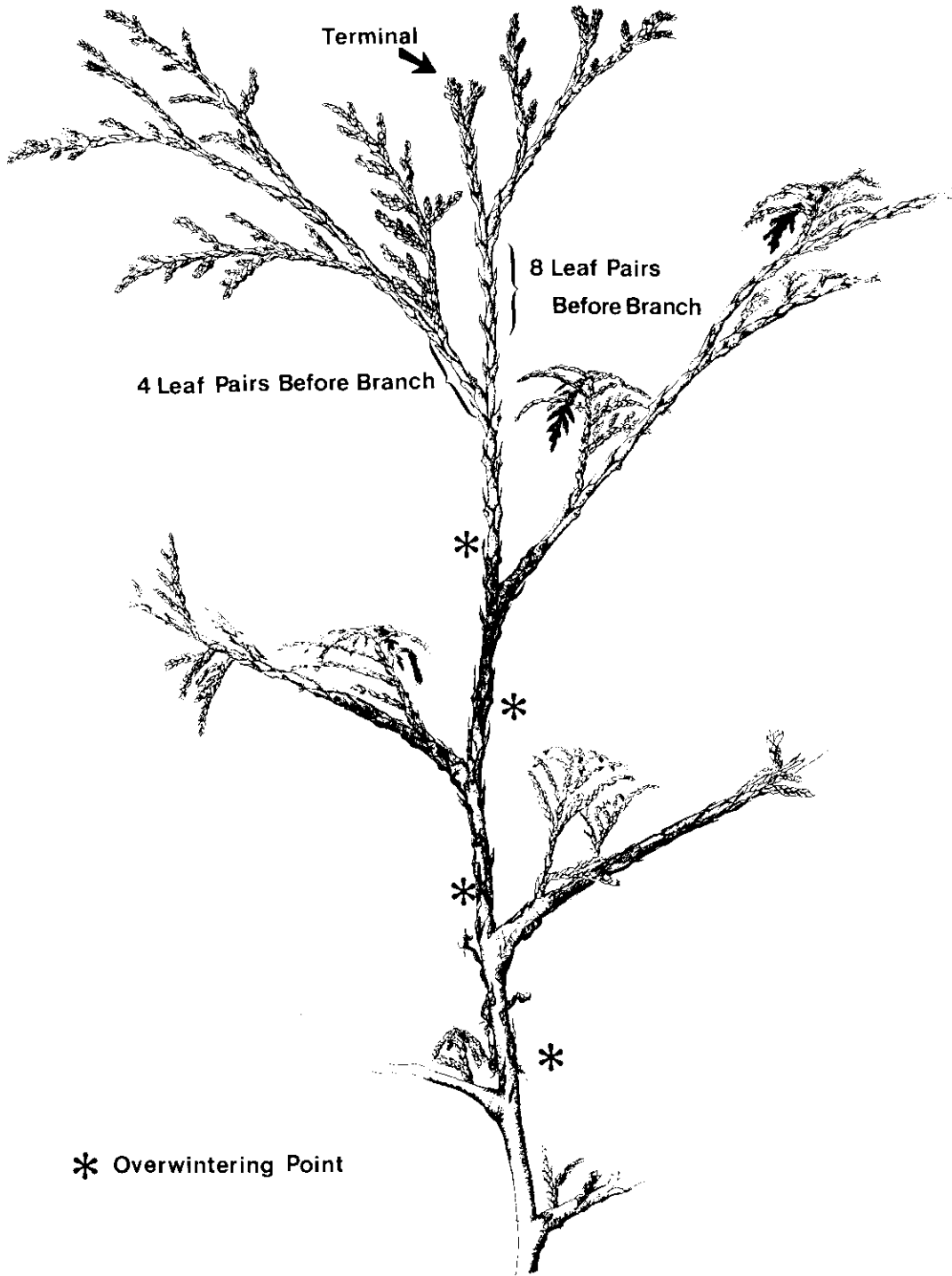


Figure 1. Branching pattern in western redcedar.

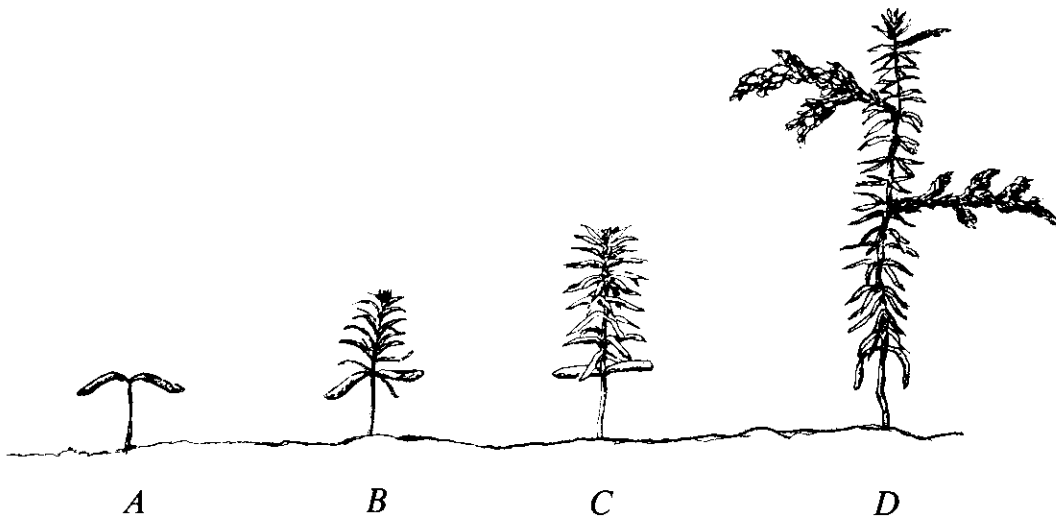


Figure 2. Seedling development in western redcedar. A-cotyledons; B,C-subulate juvenile leaves, usually ternate (B) or rarely quadrate (C); D-appearance of first mature leaves.

A terminal may produce variable numbers of branches in one growing season. We observed as many as eight branches in one year on a fast growing tree and an average of less than 0.5 branches per year on a very suppressed individual (over 28 years). Also, the distance between branches on the main stem is much less in slow growing trees than in fast growing ones. Under low light conditions lateral branches often grow longer than the terminal each year. The result is a short tree with long spindly branches. In shaded trees long branches are predisposed to being brought to the ground by gravity or litterfall and they frequently root to form vegetative clones (Habeck 1978, Parker 1979). Parker termed such individuals "veglings," along with individuals formed by other vegetative means: branches of fallen, but still rooted, trees or severed branches that root.

#### Locating the Terminal

The terminal apex is obvious in most conifers; not so in western redcedar. The tip of the terminal must be located to determine the height of an individual, and, if rate of growth over a

season is sought, it must be located periodically. In western redcedar a developing branch is often taller than the terminal and greatly resembles it. The main stem has more leaf pairs between branches than does a lateral (Figure 1). Thus, to determine which is the terminal, count the leaf pairs on both stems of a lower fork before the next branch. The stem with the most pairs in this interval will be the main stem. Repeat this counting and comparing up the stem until the terminal is reached. Frequently the leaf pairs near the terminal are telescoped, resulting in a short main stem, often shorter than, and therefore below, a developing branch.

#### Determining Past Year's Height Growth

The pattern of growth in western redcedar and the resulting form make it difficult to ascertain height growth of the past. The lack of preformed shoots enable the tree to respond to climatic variables during the immediate growth season and thus may result in great differences in tree height growth in different years. Since redcedar can average from less than one branch to eight or more per year, number of branches aids little in determining a year's leader increment.

After several seasons of observing and dissecting western redcedar stems we have found reliable indicators of yearly growth cessation and resumption. Naturally, the critical location is the overwintering point. Cedar terminals normally overwinter about 1 to 2 centimeters above a branch junction (Figure 1). On the main stem, leaves expanded during different years are different in some respect. These stem leaves usually vary in color, texture or presence, separating one year's growth from the next. The color of younger leaves is more succulent and green. The texture of the remaining leaves will vary by year of origin, including the amount they have been split by the expanding stem or even the absence of leaves, with only smooth green or brown bark remaining. These year-by-year delineations are quite consistent in the majority of cases. But, in very rapidly growing trees the leaves of a season may change dramatically in their color and form, the early formed leaves being much different from the later ones. This is mainly due to the rapid swelling of the stem, splitting leaves formed early in the growing season, and making the overwintering point less obvious. Nevertheless, annual terminal increments on most individuals can be determined for the past 3 to 5 years. Slow growing trees can often be aged beyond five years.

For aging very young seedlings the stem leaves are again used, but in their juvenile form. Cotyledons normally die after the first year but remain on the seedling, providing a starting point. Yearly height growth is again told by condition of leaves.

Practice in this technique is necessary to achieve proficiency. Using a 10x hand lens and a sharp knife, several terminals on small trees should be dissected and observed. Well down the stem (about 1/2 to 1 meter from the terminal) cut the stem and make a ring count. An oblique cut

elongates the growth rings making them easier to count. A strong light is also important. Now make a similar cross-section several branches toward the terminal and repeat the ring count. If your two dissections are the same age, they are part of the year's height growth. Keep cutting cross-sections along the stem. When two adjacent cross-sections have ring counts that vary by one year, an overwintering point, with the resulting change in stem leaves, should be visible. After some practice overwintering points on live trees will be easily recognized. Trees in the forest can then be examined and measurements made of annual growth increments without dissection.

### Conclusions

*Thuja plicata* displays morphology common to members of the Cupressaceae. Once understood, nondestructive aging of regeneration is possible, providing quick and accurate height growth information. Such information is vital for evaluating suitability of various sites and conditions for redcedar growth.

The anatomy and growth characteristics of other members of the Cupressaceae (*Chamaecyparis*, *Juniperus*, *Libocedrus*, and other *Thuja*) resembles western redcedar, suggesting the techniques presented here may be applicable.

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